SLAT NOISE REDUCTION BY MEANS OF ADAPTIVE LEADING EDGE DEVICES

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CEAS/XNOISE Workshop
AIRCRAFT NOISE REDUCTION BY FLOW CONTROL
AND ACTIVE/ADAPTIVE TECHNIQUES
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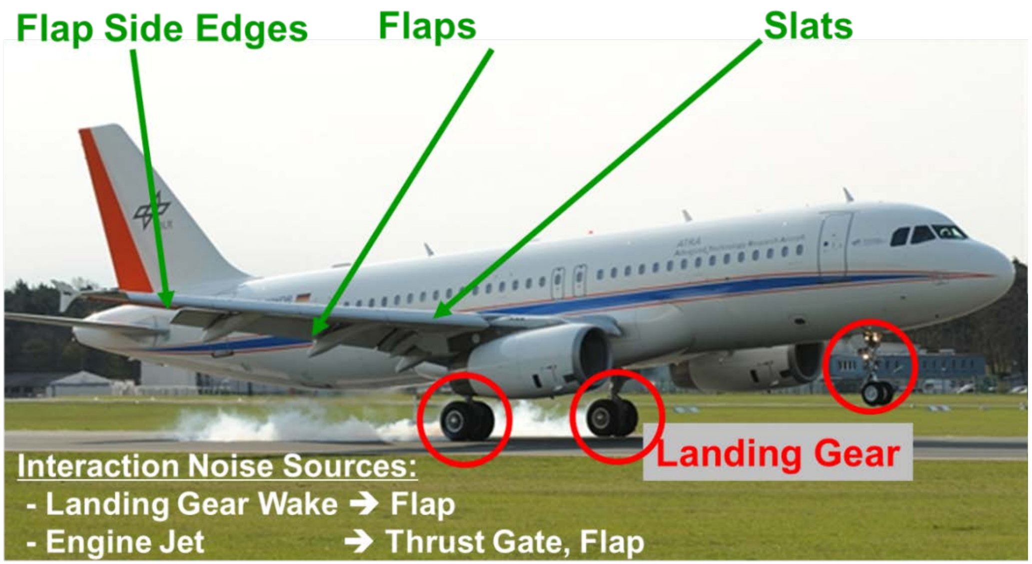
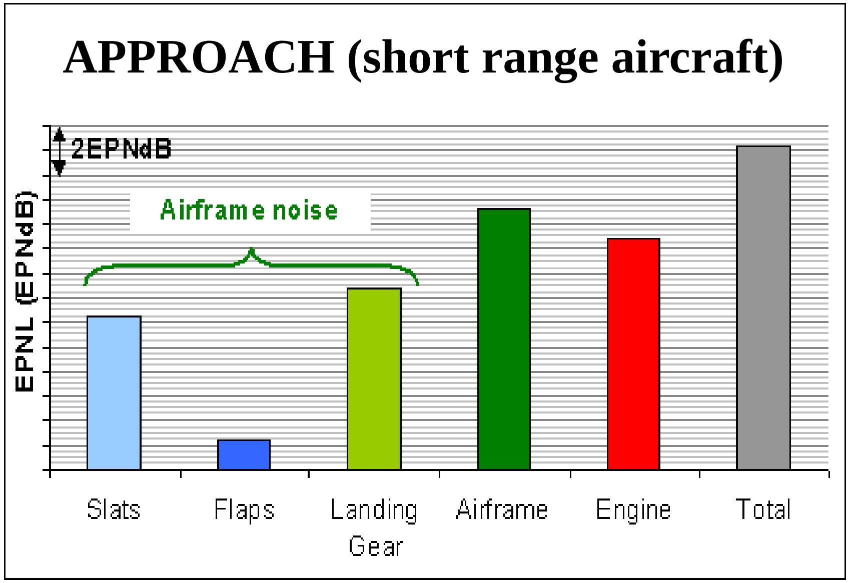
Motivation

- Typical aiframe noise sources of short and medium range aircraft

- Noise source breakdown shows slat as major noise source of the high lift system





Efforts to reduce high lift system noise should target first of all slat noise

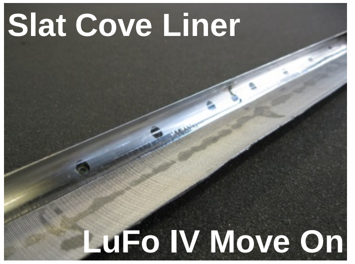
Outline

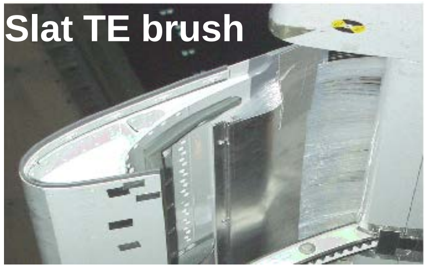
- Slat Noise reduction concepts
- Adaptive slat
  - Design objective
  - Design concept
  - Aerodynamic assessment
  - Acoustic characteristics
- Droop Nose
  - Design objective
  - Aerodynamic assessment
  - Acoustic characteristics
  - Transposition to flight
- Summary and Conclusions

Slat Noise Reduction Concepts

- Known concepts for slat noise reduction
  - Slat cove cover
  - Slat cove liner

W. Dobrzynski et al. AIAA 98-2337





EU-project RAIN

  - Brush type extensions on slat hook and/or slat trailing edge
  - Long chord slat

3-element Reference

Very Long Chord Slat

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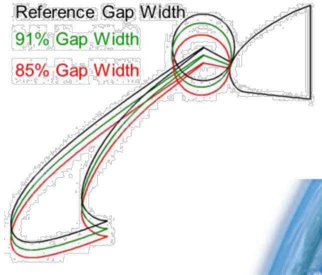
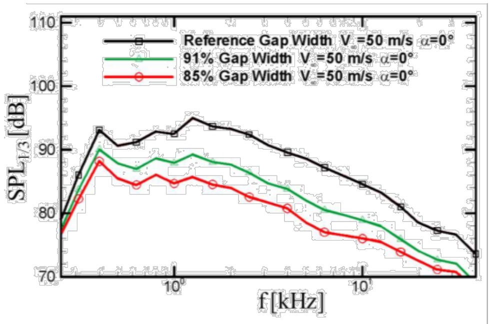
LEISA / SLED

  - **Slat gap size reduction**





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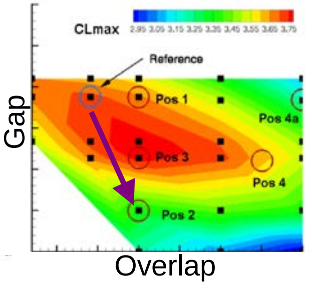
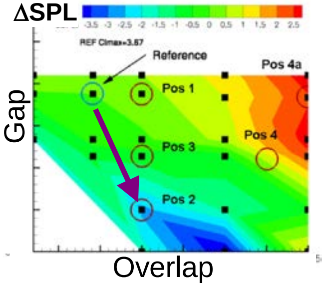
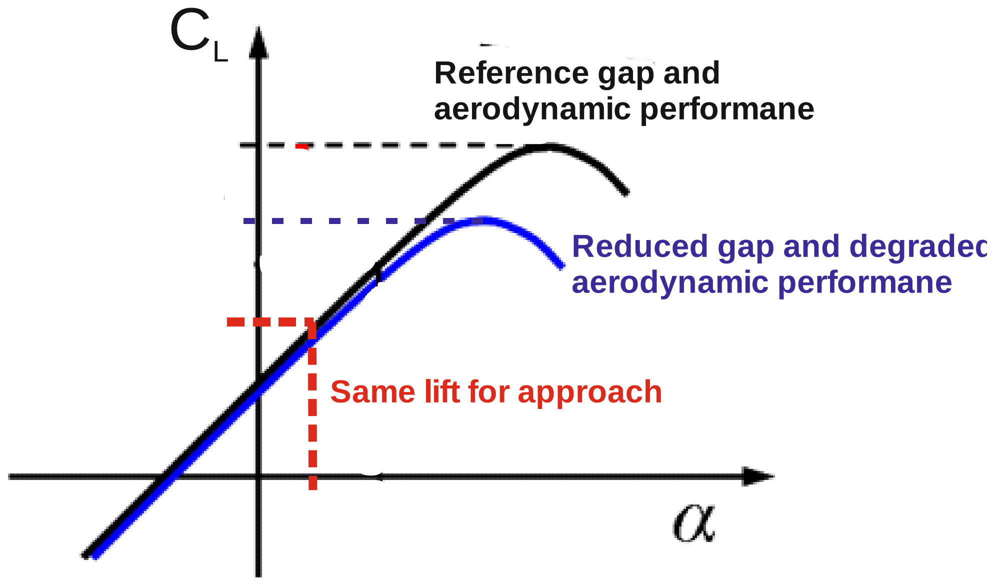


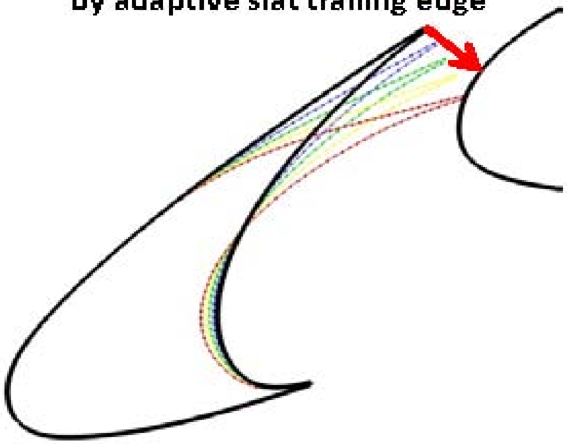


Adaptive Slat

Adaptive Slat Design Objective

- Reduce slat noise in the approach phase by means of a slat gap reduction
- Reference slat setting provides maximum aerodynamic performance
- Up to a certain level of gap reduction, the reference and the reduced gap configuration can provide the same lift during approach
  - Most efficient config.
  - Further gap reduction would result in higher flow speed due to degraded aero-performance





Adaptive Slat
Structural Analysis of a Bended Slat Trailing Edge

Aerodynamic loads in deformed case (CFD)

Deformed geometry (FE)

Grid approximation CFD/FE

Pressure coefficient for every grid point in the structure

Loads on any structural element

Non-linear solution

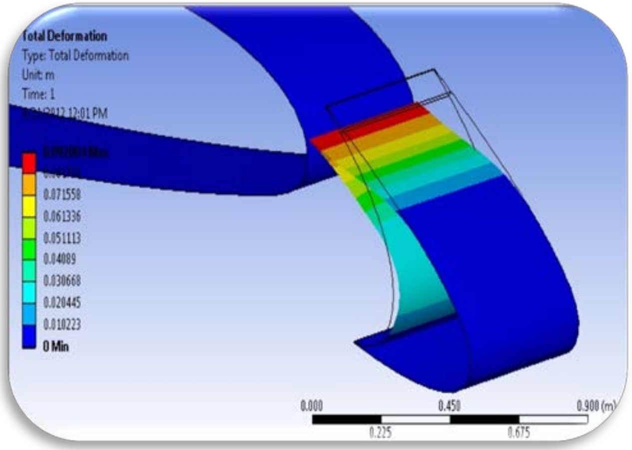
Analysis

Deviations from traget shape

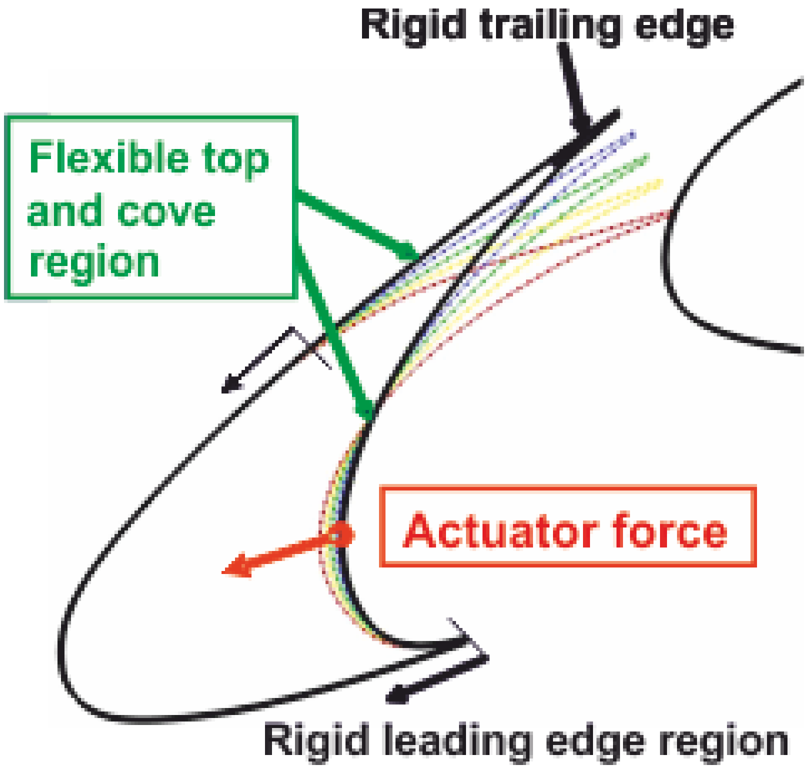
Structural deformation from aero loads

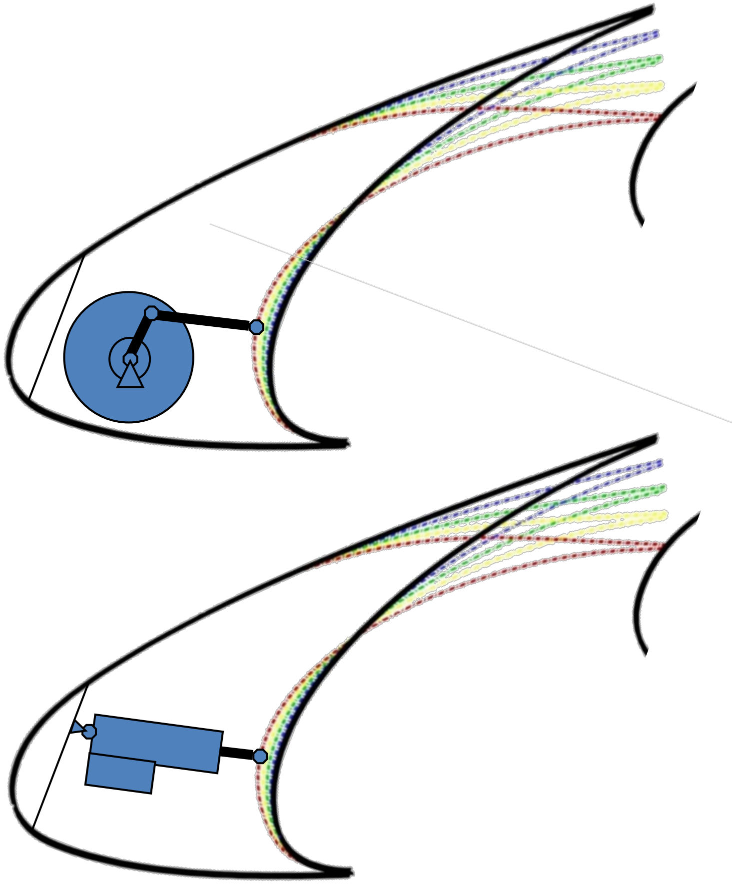
Stresses /

Actuator loads

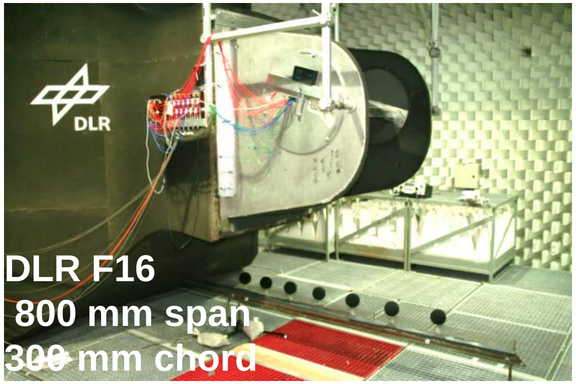


Adaptive Slat
Final Concept

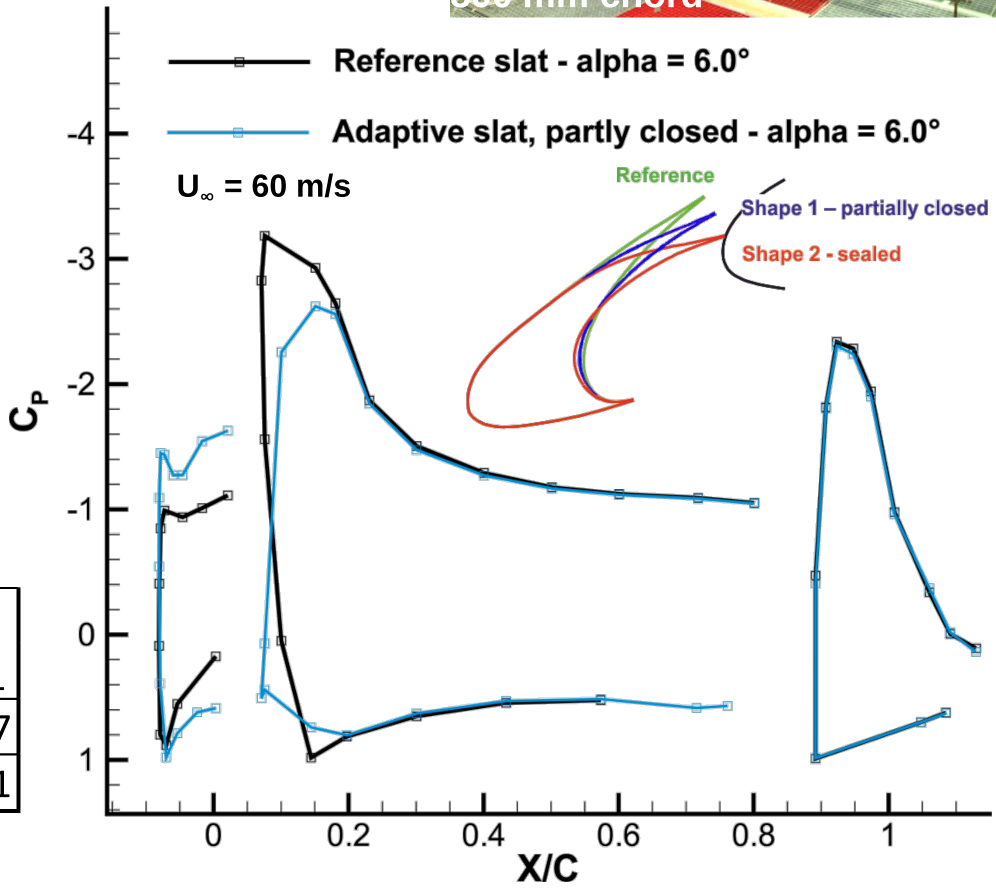




Adaptive Slat
Aerodynamic Assessment



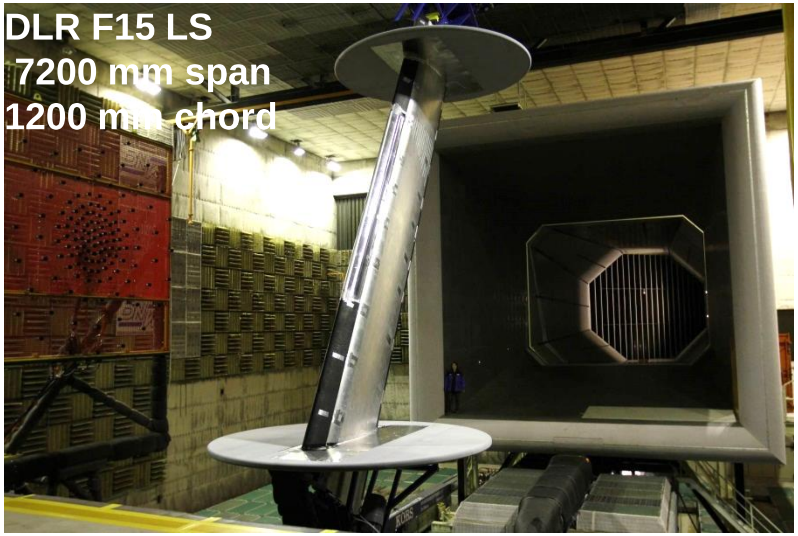
- Partly closed gap in appraoch condition:
  - Lower pressure level in suction peak on main element
  - Higher pressure level on slat suction side
- Effects balance out, finally similar lift level



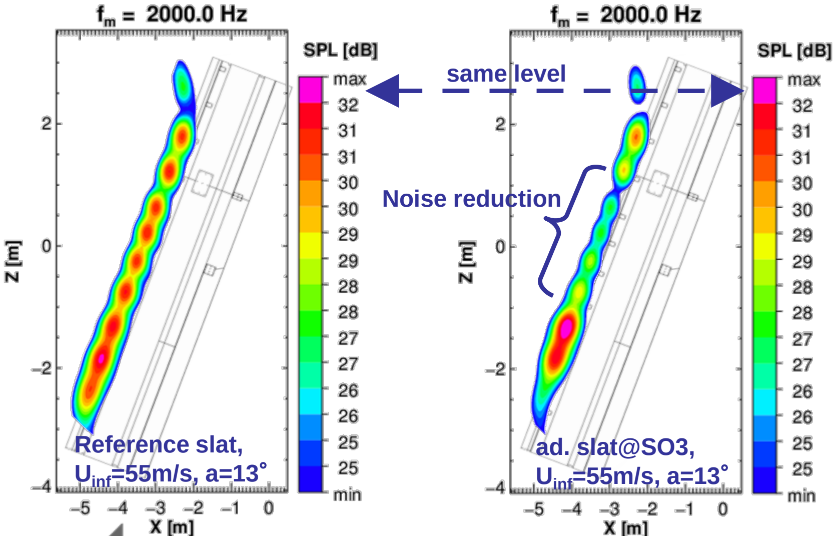
	Lift [N]			Total C_L
	Slat	Wing	Flap	
Reference	98.138	805.69	186.02	2.127
AD-Slat	149.43	778.84	184.37	2.171

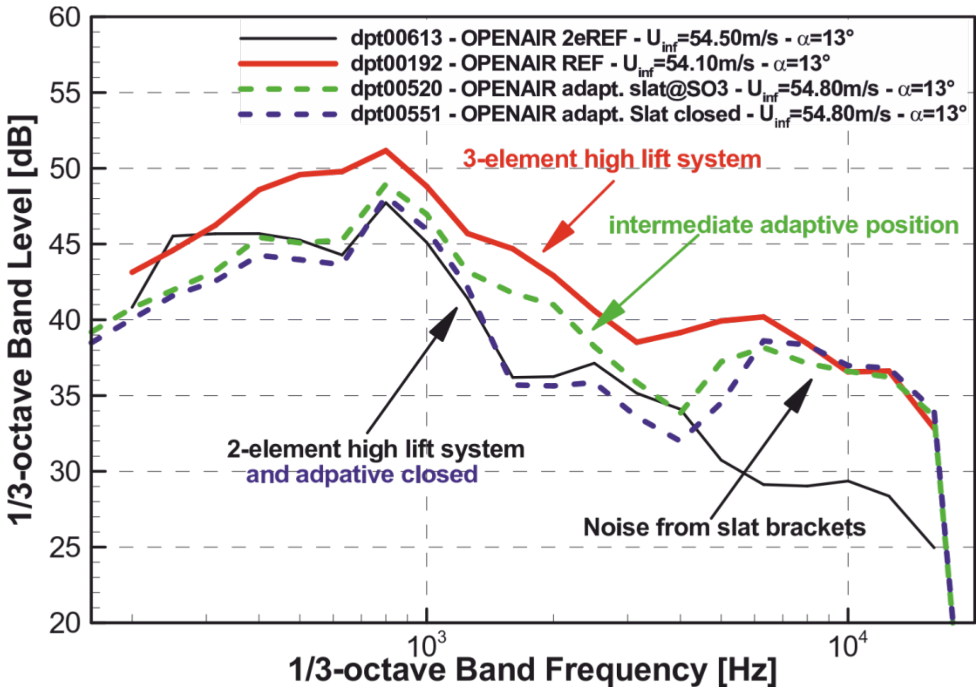
Adaptive Slat
Acoustic Characteristics

- Systematic trend: noise reduction increases the smaller the gap size
  - -45% gap →-3 to -4 dB
  - -100% gap → no slat noise



SETTINGS:	Reference Slat	Adaptive Slat@SO3
Gap [mm]	27.184	15.188
Overlap [mm]	-12.825	-6.430

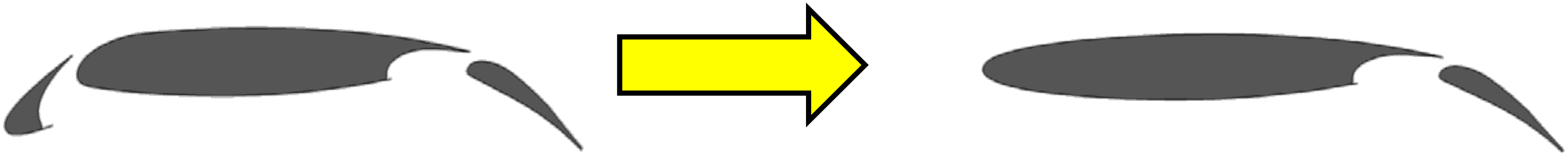




Smart Droop Nose

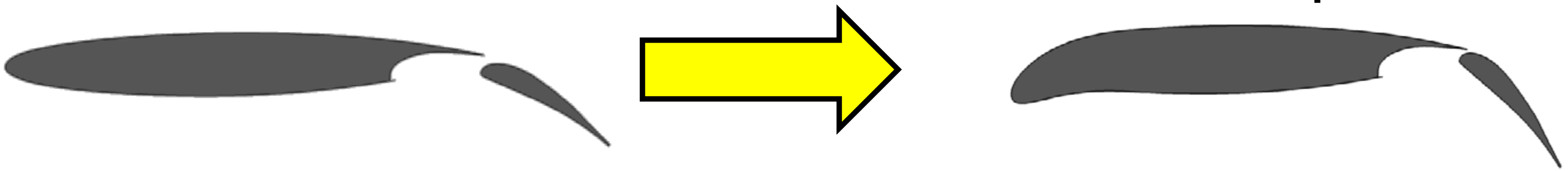
Smart Droop Nose
Design Objective

3-element Reference **2-element Reference**



- Omitt the slat
- No slat noise but aerodynamic penalty

2-element Reference **Smart Droop nose**

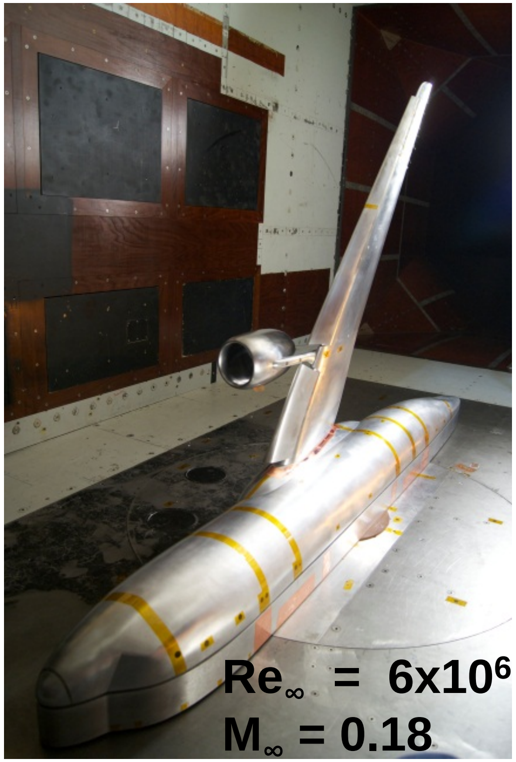


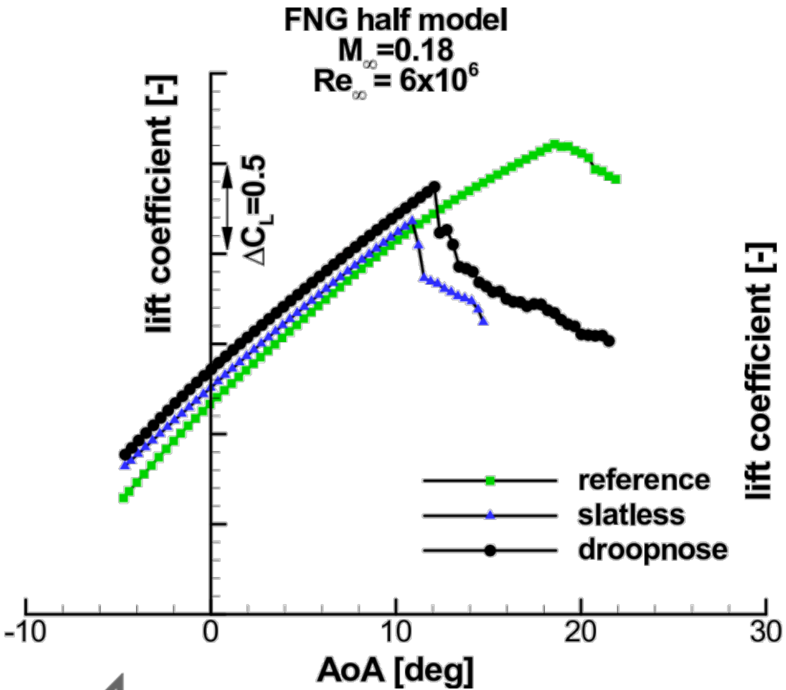
- Re-gain aero performance
- Keep source noise low

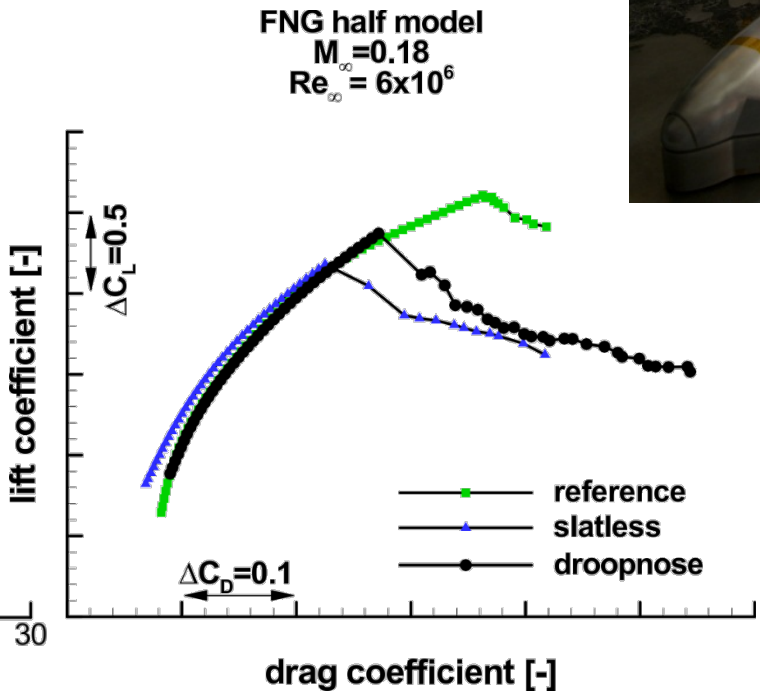
Final Design: Smart droop nose with adjusted flap seetting

Smart Droop Nose
Aerodynamic Validation in DNW-KKK

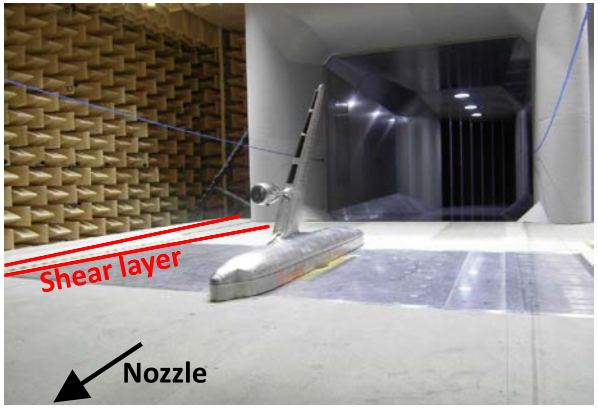
- High lift system was optimized numerically with the DLR unstructured flow solver TAU
- Validation in DNW-KKK
  - $Re_\infty = 6x10^6$ and $M_\infty = 0.18$

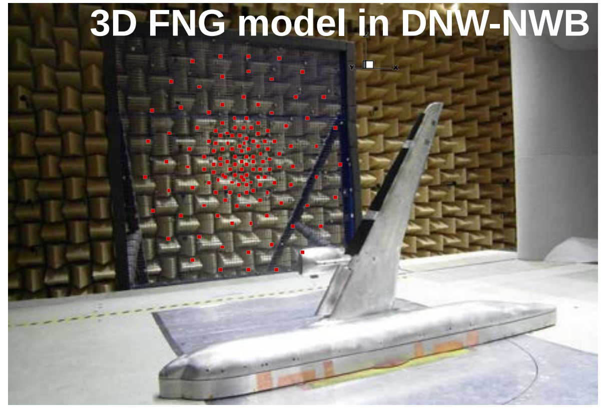






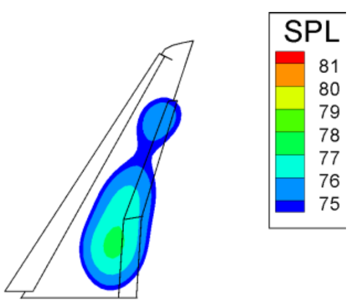
Smart Droop Nose - 3D Acoustic Assessment



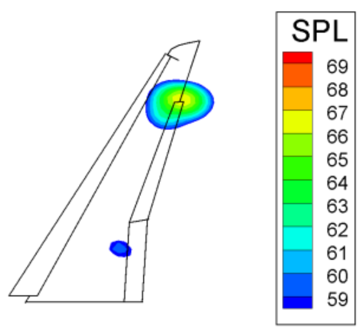


- Semi-span model
- scale 1:15.5
- span ~ 1.2 m
- flow speed up to Ma 0.2

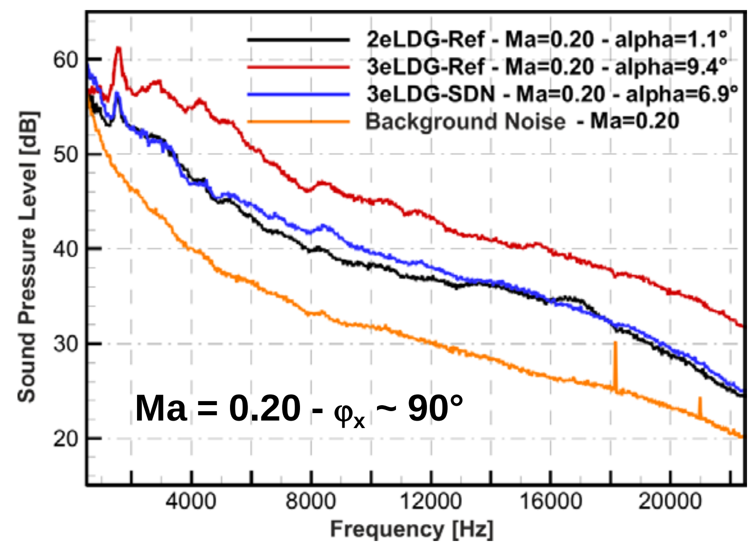
- No leading edge noise visible in case of 2-element high lift system, flap / flap side edge are dominating sources
- Smart Droop noise shows practically similar noise levels as 2-element reference.



2eRef Ldg. - 2500.00 Hz



2eRef Ldg. - 10000.00 Hz

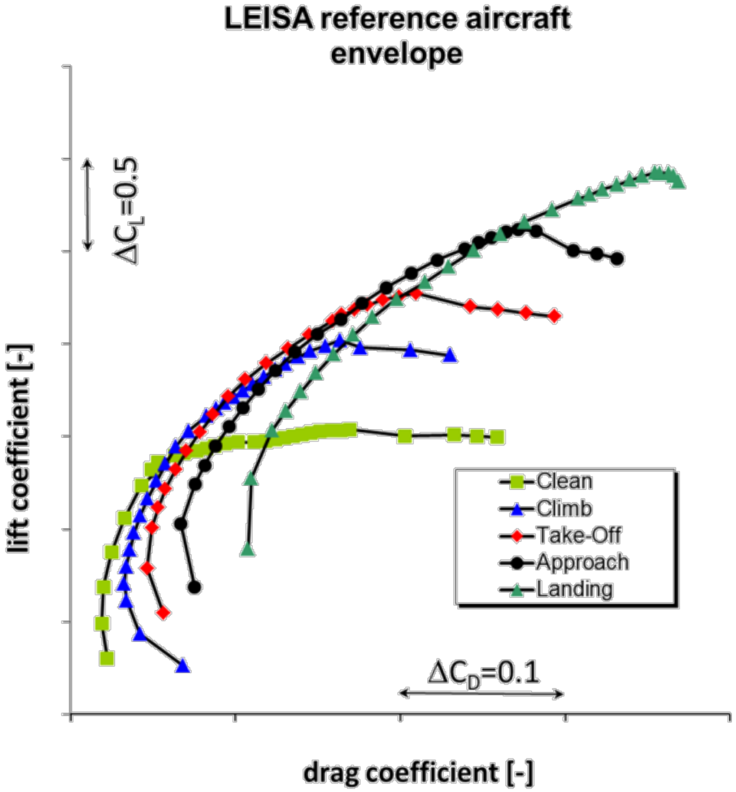


Smart Droop Noise Reference Aircraft

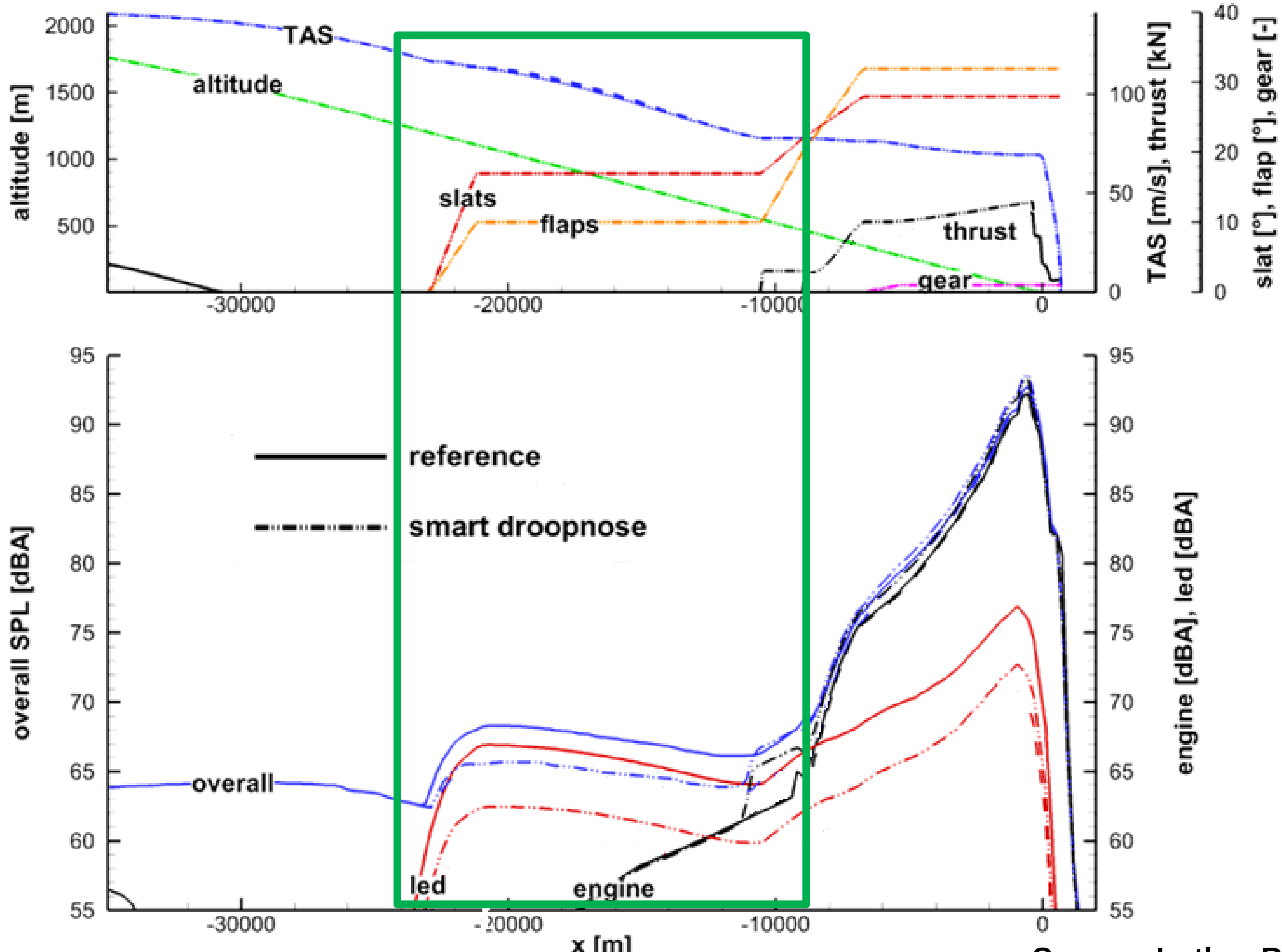
- Aircraft type:
  - Typical short to medium range twin engine configuration

- Why selected:
  - High frequency of take-offs and landings
  - Significant market share

- Design parameters:
  - 180 passengers
  - Design range 2000 NM
  - Classical double trapezoidal type wing planform
  - 3-element high lift system with slat and Fowler flap
  - Span b = 40 m



Smart Droop Nose
Transposition to Flight



Source: Lothar Bertsch, AIAA-2014-

Noise benefit due to droop nose

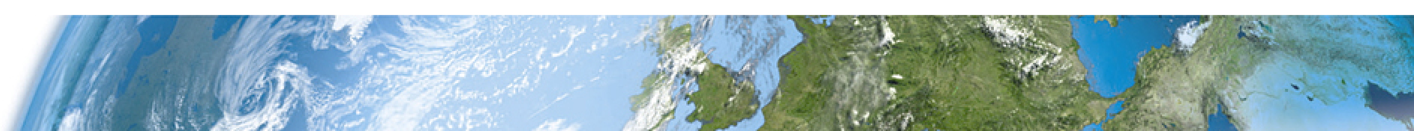
Summary and Conclusions

- Adaptive systems to reduce slat noise were presented

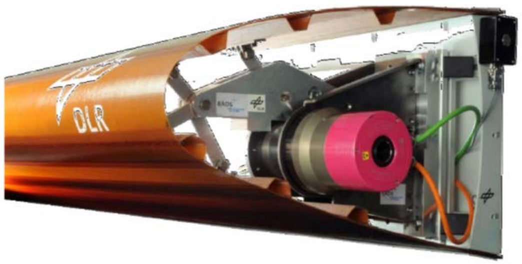
- The adaptive slat is a means to control the slat noise generation during the approach phase
- The structural mechanics assessment proved that a slat gap sealing is feasible by a proper material and actuator choice
- Noise tests showed that slat noise can be prictically canceled out by closing the gap

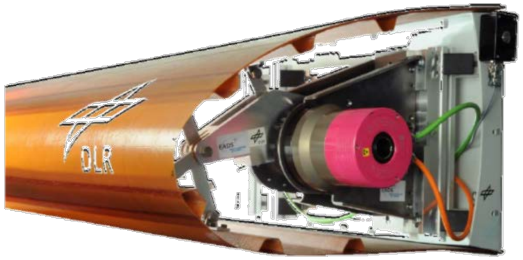
- A smart droop nose is an adaptive system to improve the aerodynamic performance of 2-element high lift systems
- Smart droop nose produces practically no noise
- Slat noise benefit is slightly reduced by high flight speed to compensate aerodynamic penalty

Thank you for your attention!

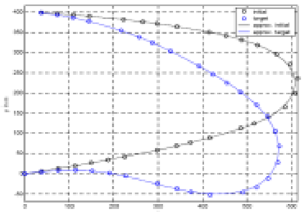


Smart Droop Nose Design Concept

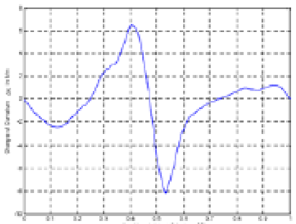




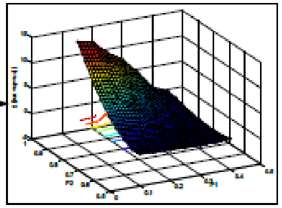
2D Vorentwurf der Hautstruktur und Kinematik



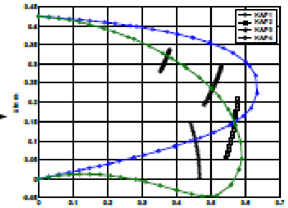
Aerodyn. Target Shape



Initial Skin Design

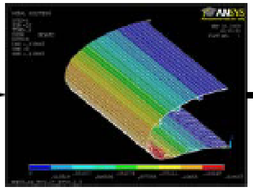


2D parametric FE, Optimized Support Positions

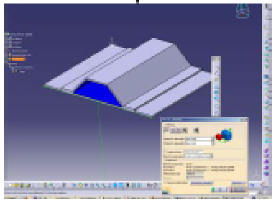


Kinematical Paths, Strains, Deformation, Stresses

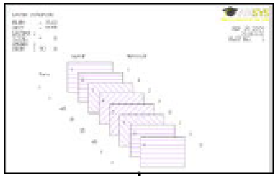
3D Detailed Design



3D FE model



Optimization of the Design of Omega-Stringers wrt. stability and strength requirements



Optimization of layer stacking sequence/ laminate layup wrt. target shape, stability and strength requirements

Feedback data for other disciplines

SADE